Woods Hole Oceanographic Institution

Applied Ocean Physics and Engineering Department, Senior Scientist

November 18, 2016

Dr. Robert Headrick
Office of Naval Research, Code 322
One Liberty Center
875 North Randolph Street, Suite 4125
Arlington, VA 22203

Dear Dr. Headrick:

Enclosed is the Final Report for ONR Grant No. N00014-15-1-2840 entitled "High Performance Computing Assets for Ocean Acoustic Research," Principal Investigator Dr. Timothy F. Duda.

Sincerely,

Gretchen McManamin

Gretchen McManamin
Administrative Assistant to Dr. Timothy F. Duda

Enclosure

cc: Administrative Grants Officer
✓Defense Technical Information Office
Naval Research Laboratory
Grant and Contract Services (WHOI)
AOPE Department Office (WHOI)

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ONR DURIP Grant Final Report
High Performance Computing Assets for Ocean Acoustics Research

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LONG TERM GOALS

The goal of this project was to procure computing equipment configured for our ocean acoustics research. This work benefits from a strong computational capability. Limits of computational accuracy can be tested against theory, practicality of computational methods can be determined, and studies of underwater acoustics phenomena can be undertaken with computational methods.

OBJECTIVES

The three-dimensional acoustic propagation models that we depend on at this time are not written in codes that make them easily parallelizable in the manner that, for example, atmospheric or ocean general circulation models (GCMs) are parallel. Many GCMs can split a three-dimensional computational domain in to subdomains and pass the boundary conditions back and forth, and each subdomain can be run independently on processing units with access to a typically available amount of memory, say 16 or 32 gigabytes. Our models require each processor to have access to up to 500 gigabytes of memory in their current configurations, although meaningful results can be obtained with 64 gigabytes if the frequency is kept below 1000 Hz and the water depth is less than 1500 m.

As an alternative to completely reformulating our computational methods to allow results to be obtained with limited amounts of memory available to individual processing units (with no time frame for successful completion known at this time), we sought to obtain powerful computational engines, which are routinely available, that are compatible with the architectures of our models.

APPROACH

As outlined above, each processor in the acoustic calculation must access a large amount of memory at this time. This is incompatible with most current-generation High-Performance Computing Clusters, which have thousands of linked processors, but with the clusters grouped into nodes of 16 or 32 each with direct access only to memory allocated to that node. Many computational tools are written so that the problem can be divided into segments solvable on many processor units each needing only a subset of the total required memory. This is not true for current generation 3D acoustic parabolic equation solvers.

Our straightforward approach to increase our computing capacity was to purchase specialized computer workstations with a large amount of memory accessible by all of the processors. We have purchased three workstations, each with many CPU cores to enable parallel computing, with all memory space available to every core.

WORK COMPLETED

Three desktop workstations have been procured, tested, and put into use. One file server computer to store simulation output has also been purchased. The first workstation has 28 CPU cores, dual-thread, (56 processors, effectively), and 512 GB memory. The second has 24 CPU cores, dual-thread, (48 processors, effectively), and 512 GB memory. The third has 28 CPU cores, dual-thread, (56 processors, effectively), and 256 GB memory. Mr. Arthur Newhall of WHOI worked with the vendors to secure the best prices for workstations of the highest capability.

Two figures show aspects of a test of Workstation 1. 1000-Hz sound is simulated to propagate eastward up a slope and into a canyon from San Diego Trough (Figure 1). The split-step Fourier code described in Lin et al. (2013) is used, with computational grid of 32,768 by 32,768 implements for each marching step. The propagation distance is 13.6 km and the domain width is over 8 km. Compute wall-clock time is 210 hours, with 14 threads used for acoustic medium interpolation and 28 threads used for propagation (can possibly run faster). This uses a maximum of ~250 gigabytes memory.

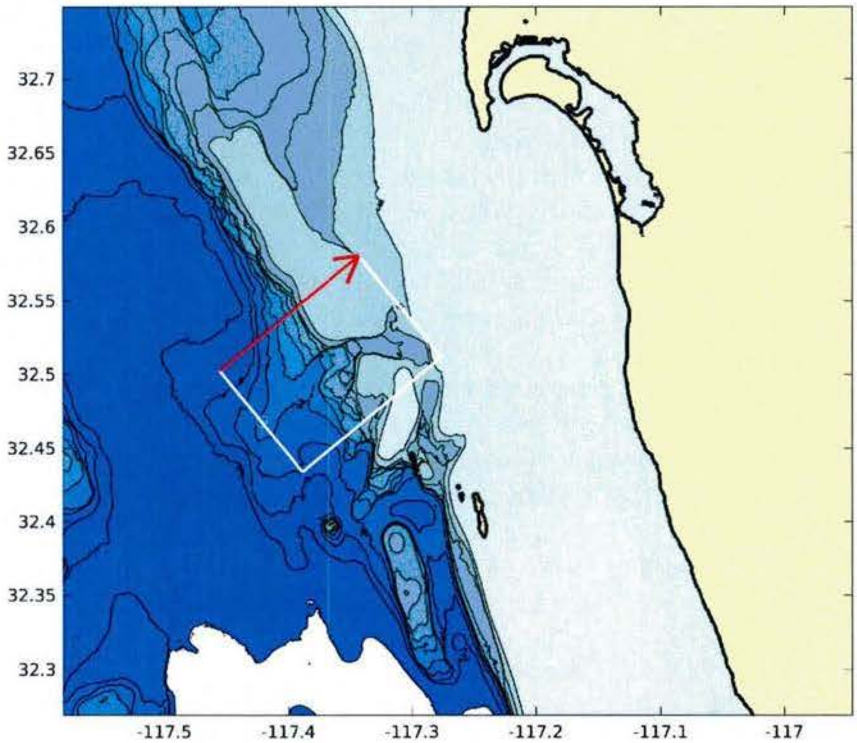

Figure 1. The test domain is shown. San Diego Bay is at the top right. The bathymetry is shown with 100-m filled contours. The box shows the x/y limits of the computational domain with the source shown with a circle along the x=0 side and the arrow pointing in the positive x (propagation) direction.

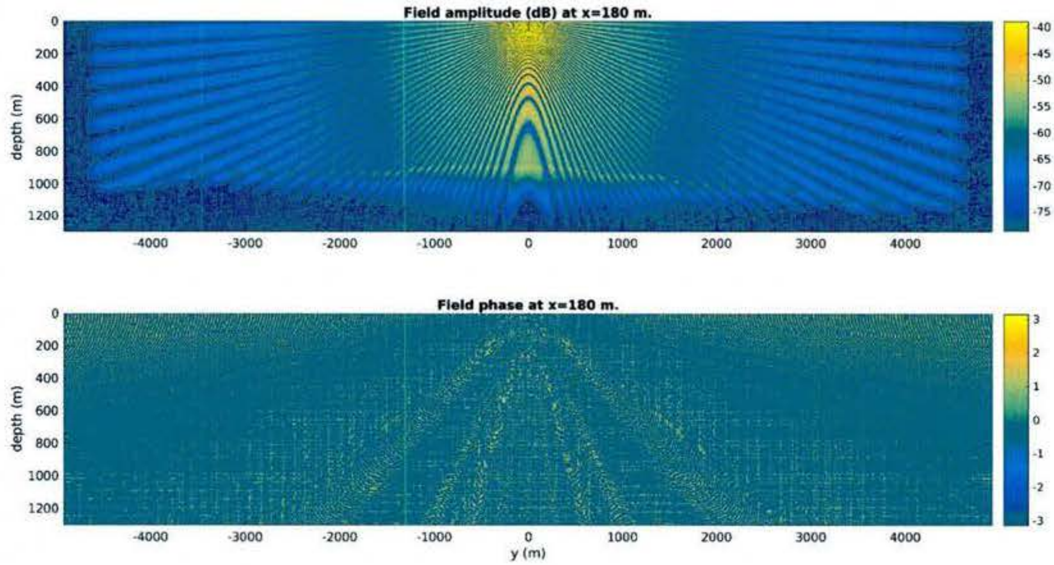

Figure 2. The magnitude and phase of the computed field at range x=180 m (lose to the source) are shown at the top and bottom, respectively, Source level is 0 dB. The point source is at 25 m depth.

Purchased Item Specifications:

Workstation 1: From Pogo Linux, Inc.
Velocity D58SQ:
Whisper Quiet Workstation (28dB) with High-end Graphics Support
- Dual Intel Xeon E5-2600v3 series with QPI up to 9.6GT/s
- Up to 1TB DDR4 ECC Registered DIMM
- Intel Dual i210 Gigabit Ethernet Controller
- 8 x 3.5" hot-swap SAS/ SATA Drive Bays
- 1200W Low-Noise High Efficiency Power Supply

2 Intel Xeon E5-2695v3 2.3GHz 35MB Cache 9.6GT/s *(total cores 28, threads 56)*
1 512GB DDR4 2133MHz ECC Reg (16 x 32GB)
1 Intel S3510 Series 1.6TB MLC SSD 6Gb/s
1 Seagate Constellation ES.3 2TB 7200RPM 128MB SATA 3.0 HDD
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1 Seagate Constellation ES.3 2TB 7200RPM 128MB SATA 3.0 HDD
1 Seagate Constellation ES.3 2TB 7200RPM 128MB SATA 3.0 HDD
1 LSI MegaRAID SAS 9361-4i 12Gb/s SAS Controller
1 NVIDIA Quadro K2200 4GB PCI-E 1x DVI/2x DisplayPort
1 Intel 10G Dual Port RJ45 Ethernet Adapter
1 SATA 24x DVD-RW 5.25"
1 No Operating System. Include testing and customer OS preference in notes.
1 Custom RAID Configuration - Add instructions to system notes
1 Logitech Desktop MK120
1 Creative Inspire P7800 7.1 Speaker System
1 Samsung SyncMaster 24IN WS LCD 1920X1200
1 Return to Depot Warranty (3 Year Hardware Warranty with Standard Advance Parts Replacement)
Notes: Install and test with latest stable version of Linux Mint

Data-storage unit (file server): From Thinkmate
STX-JB JE16-0310-SAS3
Power Estimate: Watts: 158.4, Volt-Amps: 162.36, BTU/h: 540.46,
Amps(110V): 1.44, Amps(208V): 0.76
- Supermicro SuperChassis 836BE1C-R1K03JBOD - 3U - 16 x 3.5" SAS3 - 12Gb/s Single Expander - 1000W Redundant
- 16 x 8.0TB SATA 6.0Gb/s 7200RPM - 3.5" - Hitachi Ultrastar He8 (512e)
- Use an existing Host Server or Adapter
- 3 Year Advanced Parts Replacement Warranty

Workstation 2: From Pogo Linux, Inc:
Velocity D58SQ
Whisper Quiet Workstation (28dB) with High-end Graphics Support
- Dual Intel Xeon E5-2600 v4 series with QPI up to 9.6GT/s
- Up to 1TB DDR4 ECC Registered DIMM
- Intel Dual i210 Gigabit Ethernet Controller
- 8 x 3.5" hot-swap SAS/ SATA Drive Bays
- 1200W Low-Noise High Efficiency Power Supply

2 Intel Xeon E5-2687Wv4 12C 3.0GHz 30MB Cache *(total cores 24, threads 48)*
1 512GB DDR4 2133MHz ECC Reg (16 x 32GB)
1 Intel S3610 Series 1.2TB MLC SSD 6Gb/s
1 Seagate Constellation ES.3 2TB 7200RPM 128MB SATA 3.0 HDD
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1 NVIDIA Quadro K2200 4GB PCI-E 1x DVI/2x DisplayPort
1 Intel 10G Dual Port RJ45 Ethernet Adapter
1 SATA 24x DVD-RW 5.25"
1 No Operating System. Include testing and customer OS preference in notes.
1 Custom RAID Configuration - Add instructions to system notes
1 Logitech Desktop MK120
1 Samsung SyncMaster 24IN WS LCD 1920X1200
1 Return to Depot Warranty (3 Year Hardware Warranty with Standard Advance Parts Replacement)
Notes: Install and test with latest stable version of Linux Mint

Workstation 3: From Pogo Linux, Inc:
Velocity D58SQ
Whisper Quiet Workstation (28dB) with High-end Graphics Support

- Dual Intel Xeon E5-2600 v4 series with QPI up to 9.6GT/s
- Up to 1TB DDR4 ECC Registered DIMM
- Intel Dual i210 Gigabit Ethernet Controller
- 8 x 3.5" hot-swap SAS/ SATA Drive Bays
- 1200W Low-Noise High Efficiency Power Supply

2 Intel Xeon E5-2680v4 14C 2.4GHz 35MB Cache *(total cores 28, threads 56)*
1 256GB DDR4 2133MHz ECC Reg (8 x 32GB)
1 Intel S3610 Series 800GB MLC SSD 6Gb/s
1 Seagate Constellation ES.3 2TB 7200RPM 128MB SATA 3.0 HDD
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Notes: Install and test with latest stable version of Linux Mint

REFERENCES

Lin, Y.-T., T. F. Duda and A. E. Newhall, Three-dimensional sound propagation models using the parabolic-equation approximation and the split-step Fourier method, *J. Comput. Acoust., 21,* 1250018, doi: 10.1142/S0218396X1250018X, 2013.

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